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12 February 2015

Version of attached file:

Presentation

Peer-review status of attached file:

Peer-reviewed

Citation for published item:

Mankowski, O.A. and Sims-Williams, D.B. and Hunt, A. and Dominy, R.G. (2014) 'An active turbulence generation system for the simulation of aerodynamic transients in a model wind tunnel.', First International Conference in Numerical and Experimental Aerodynamics of Road Vehicles and Trains (Aerovehicles 1). Bordeau, France, 23-25 June 2014.

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Aerovehicles 1

An Active Turbulence Generation System for the Simulation of Aerodynamic Transients in a Model Wind Tunnel,

Bordeaux, France, June 2014

O.A. Mankowski, D.B. Sims-Williams A. Hunt and R.G. Dominy.
Corresponding author: r.g.dominy@durham.ac.uk

Durham University, UK

Abstract: This paper outlines the creation and validation of an active turbulence generation system (TGS) for the simulation of wind and vehicle-induced transients in a model scale, ¾ open jet, wind tunnel.

Keywords: Aerodynamics, ground vehicles, experiments, flow control, turbulence, wind

1 Problem Statement

The aerodynamic transients that are experienced by passenger vehicles can be important in terms of both vehicle response and aeroacoustics and in general it is cross wind transients that are most significant for road vehicles. These transients include a broad range of length scales but it has been shown that the most important are in the in the range 8-80 metres where high levels of unsteadiness are experienced, the admittance is likely to be high, and the reduced frequencies indicate that dynamic testing is required to correctly determine a vehicle's aerodynamic response [1].

Using data collected from a passenger car driven on the road under a broad range of wind conditions it has been shown that for a typical passenger car an effective turbulence generation system should achieve yaw angles of up to 8°, which equates to lateral turbulence intensities of 10%, with a frequency range extending up to 10 Hz [1]. There is a very considerable body of literature relating to the generation of turbulence in wind tunnels using passive grids but the creation of these length scales, which are of comparable magnitude to the length of a typical passenger car, are impractical using passive grids. The alternative is to use some form of active turbulence generation and it is that approach that has been developed in the study presented here.

2 Results and discussion

The resulting TGS system has been incorporated into the Durham University 2m, ¾ open jet wind tunnel. The wind tunnel was constructed primarily for the testing of passenger cars and includes interchangeable fixed and moving ground planes but it is also used for studies on trains and aircraft. The TGS solution uses a pair of vertical airfoils either side of the inlet to the test section which can be yawed at high frequency to create either sinusoidal or arbitrary motion (figure 1). The use of just two foils avoids the possibility of their wakes impinging on the model. However, at the most extreme yaw angles the shear layers lie close to the model so under these conditions additional shutters are opened on the windward side of the inlet to broaden the jet. The yawing of the inlet flow requires careful handling at the downstream end of the test section and additional outlets were added here with cascading shutters to control both collector width and its effective lateral location. At the top of the test section inlet is mounted a horizontal aerofoil which allows a vertical component to be added to the flow transient.

Evaluation of the TGS showed that the maximum steady state yaw angle range achieved was ±8° steady state, extending to ±11° in dynamic operation at 10Hz, thus achieving the appropriate design objectives. An important design consideration was that under steady state test conditions the yawed flow created by the TGS should not differ significantly from the flow that is experienced when the car is yawed in the 'standard' wind tunnel using a turntable only.

A particular feature of the system is that it can be programmed to reproduce specific wind events as measured on the road, with time appropriately scaled for model testing. Those events arise from a combination of the natural wind environment, the modification of that environment by roadside obstacles, other vehicles and the motion of the car itself through the resulting turbulent structures. Figure 2 shows the wind tunnel replication of a specific yaw vs time trace originally measured on the road, with the corresponding forces on the model in the tunnel measured with a piezoelectric balance. Figure 3 shows the quantification of vehicle dynamic response using an admittance approach.

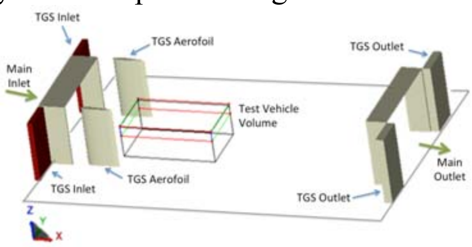

Figure 1: Schematic illustration of the turbulence generation system.

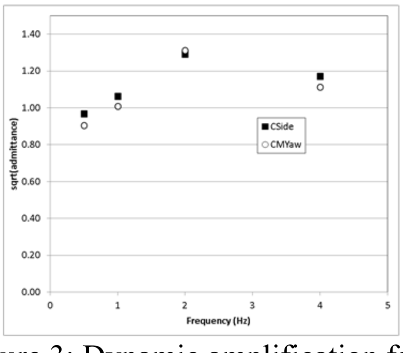

Figure 3: Dynamic amplification factors for side force and yawing moment.

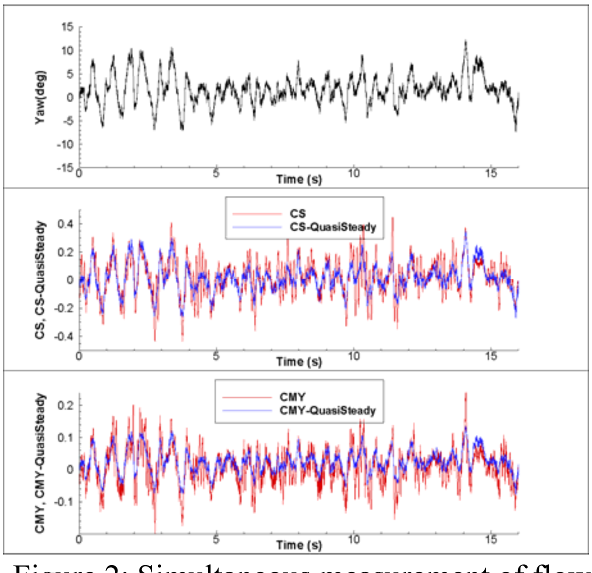

Figure 2: Simultaneous measurement of flow, side force and yawing moment.

References

[1] Mankowski, O.A., Sims-Williams, D.B., Dominy, R.G., "A Wind Tunnel Simulation Facility for On-Road Transients", SAE Paper 2014-01-0587, SAE World Congress, Detroit, 2014.